Continued Analysis of SHOWEX Data

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LONG-TERM GOAL

Our long-term goal in this project is to understand, using data collected by our airborne microwave radar, CORAR, the propagation of surface waves longer than about 30 m from the deep ocean into the coastal zone.

SCIENTIFIC OBJECTIVES

Our scientific objectives are to investigate the generation of forced waves produced by quadratic nonlinearities, the refraction of swell in shallow water, the possibility of determining bottom topography from refraction, and the effects of bottom topography and composition on the reflection and attenuation of swell propagating shoreward.

APPROACH

Our approach has been to fly a coherent real aperture radar (CORAR) on the CIRPAS Twin Otter aircraft in order to make images in a sidelooking mode of the waves propagating toward and away from shore. From these images and data collected in a simultaneous rotating mode we attempt to compute directional wave spectra. The accompanying wind speed can also be determined from the rotating mode. We flew along with two NOAA radiometers that measured air/water temperature difference as well as wind speed and direction. Finally, we flew in formation with a NOAA LongEZ airplane that measured atmospheric winds and attempted to measure directional wave spectra at low altitude. We will compare our measurements with theirs.

WORK COMPLETED

Data were collected simultaneously in the sidelooking and rotating modes during the main SHOWEX experiment in October and November, 1999. Subsequent analysis revealed that the incorrect antenna pointing direction had been used in the real-time corrections of the motion-induced Doppler shift in the rotating antenna. Thus the frequency modulated part of that data was not able to be utilized. All other data collected by CORAR seemed to be of very high quality. We have analyzed one especially perspicuous day, November 16, 1999 and shown that waves generated by a wind blowing obliquely offshore on the Maryland/Virginia coast propagate to the North Carolina coast where they become shoaling waves. We have now submitted a paper to the Journal of Oceanic and Atmospheric

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14. ABSTRACT
Our long-term goal in this project is to understand, using data collected by our airborne microwave radar, CORAR, the propagation of surface waves longer than about 30 m from the deep ocean into the coastal zone.

15. SUBJECT TERMS

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Technology detailing our techniques and reporting these results (Plant, et al., 2003). Our activities over the last year have consisted of analyzing the other 16 days of data collected during SHOWEX to obtain directional wave spectra and wind vectors, and to compare these wind vectors with those collected by other instruments during SHOWEX. Directional wave spectra have now been obtained from all days flown when the wind speed was above 3 m/s and the comparison of wind vectors obtained by various sensors has nearly been completed.

RESULTS

Initial results showed that directional spectra could be extracted from both the AM and FM parts of the sidelooking imagery and from the AM part of the rotating mode data. However, subsequent attempts to convert these spectra to calibrated wave spectra indicated that many times wave spectra derived from the AM products did not agree with those obtained from the FM part of the imagery. Directional wave spectra obtained from the FM part of the imagery showed very well defined features that could be related to wind direction and bottom features. Many features of these spectra could be modeled well using relationships obtained during the three-decade old JONSWAP (Plant, et al., 2003). We have therefore concluded that spectra of received power cannot be easily related to directional wave spectra due to an insufficient knowledge of power modulations induced by waves and wind. For now we have set aside our attempts to better understand these modulation processes and concentrated on the simultaneous wave spectra and wind vectors that can be obtained from the FM part of the sidelooking mode and the AM part of the rotating mode.

These simultaneous wind and wave data obtained by CORAR have proven to be very valuable. We have now analyzed data from all days during SHOWEX on which our instruments were flown. We made one flight near Cape Hatteras where the Gulf Stream makes its closest approach to land in hopes of finding effects of the Stream on the wind and waves. Figure 1 summarizes the wind and wave vectors that we found on this flight.

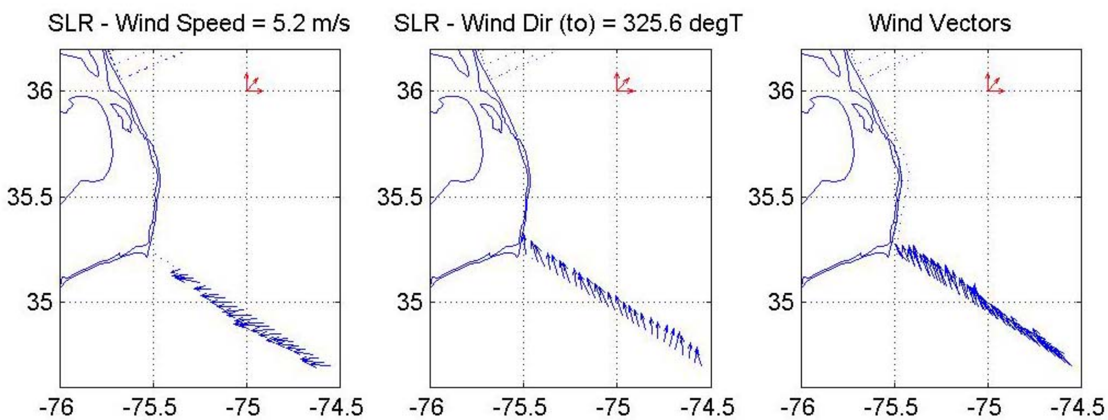

Figure 1. The two left plots show the wave vectors of the two primary wave trains arriving at Cape Hatteris from the Atlantic while the right plot shows simultaneously measured wind vectors. The wind speed and direction shown at the top are averages over the whole flight.

As the figure shows, the Gulf Stream had a rather dramatic effect on the measured wind vector, veering it so that it came more from the south over the Stream compared to the wind on the south side of the Stream or on the north side, close to land. In comparison, a signature of the Gulf Stream is much more difficult to discern in the wave vectors of the two wave systems that are shown in the two plots on the left of the figure.

Our comparisons of wind vectors obtained by various instruments during SHOWEX has revealed an interesting discrepancy between the two measurements of wind derived from scatterometry. One of these is the wind determination made by the rotating part of CORAR, a deduction from scatterometry at X-band, 10 GHz. The other is the high-resolution wind field produced by David Long from QuikSCAT data, a deduction from scatterometry at Ku-band, 14 GHz. The observation is that the two derived wind fields, evaluated at the same spatial locations, seem to agree under stable atmospheric conditions but to disagree under unstable conditions. Figures 2 and 3 illustrate this result.

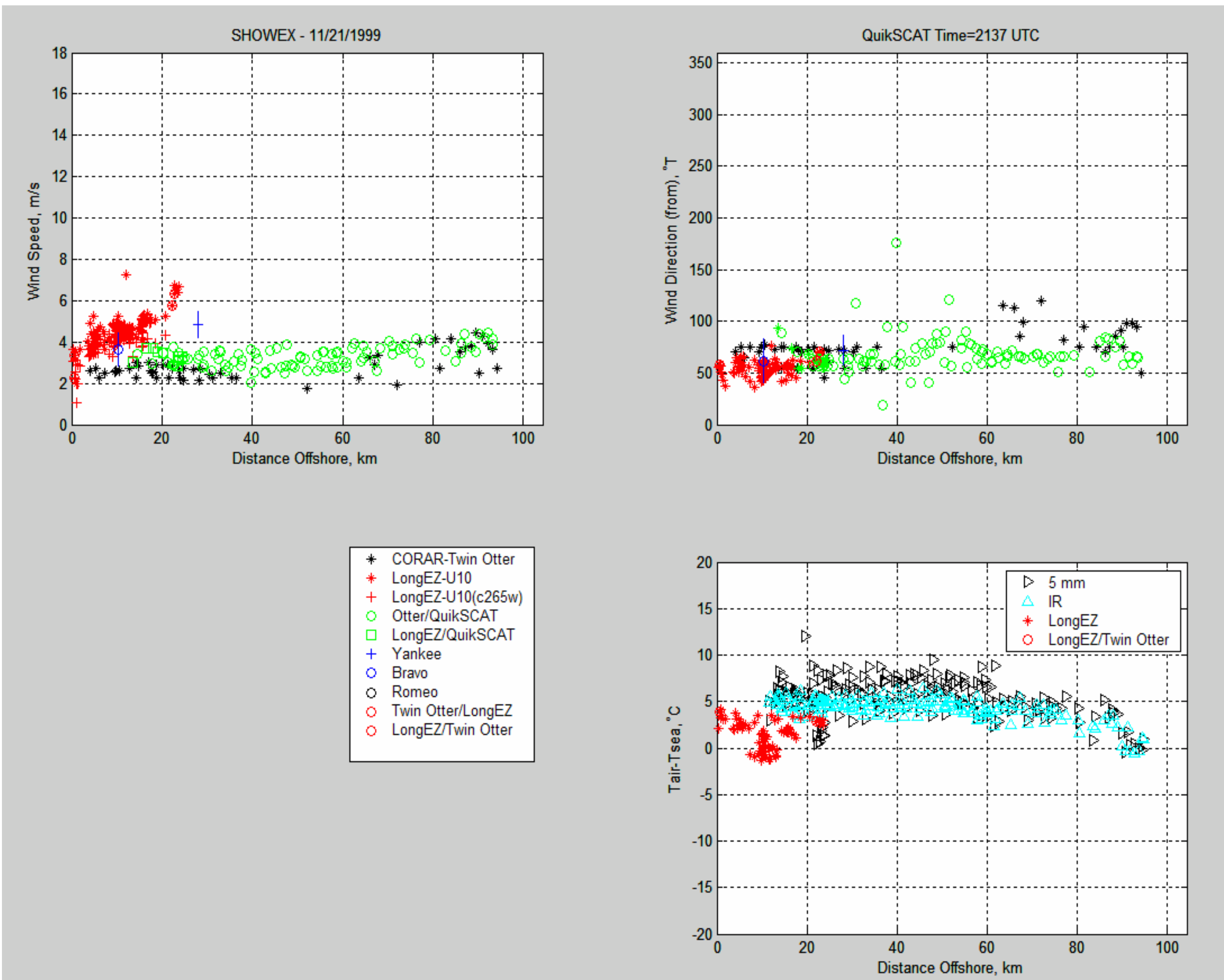

Figure 2. Comparison of CORAR winds with high-resolution QuikSCAT winds on a day when the atmosphere was stable.

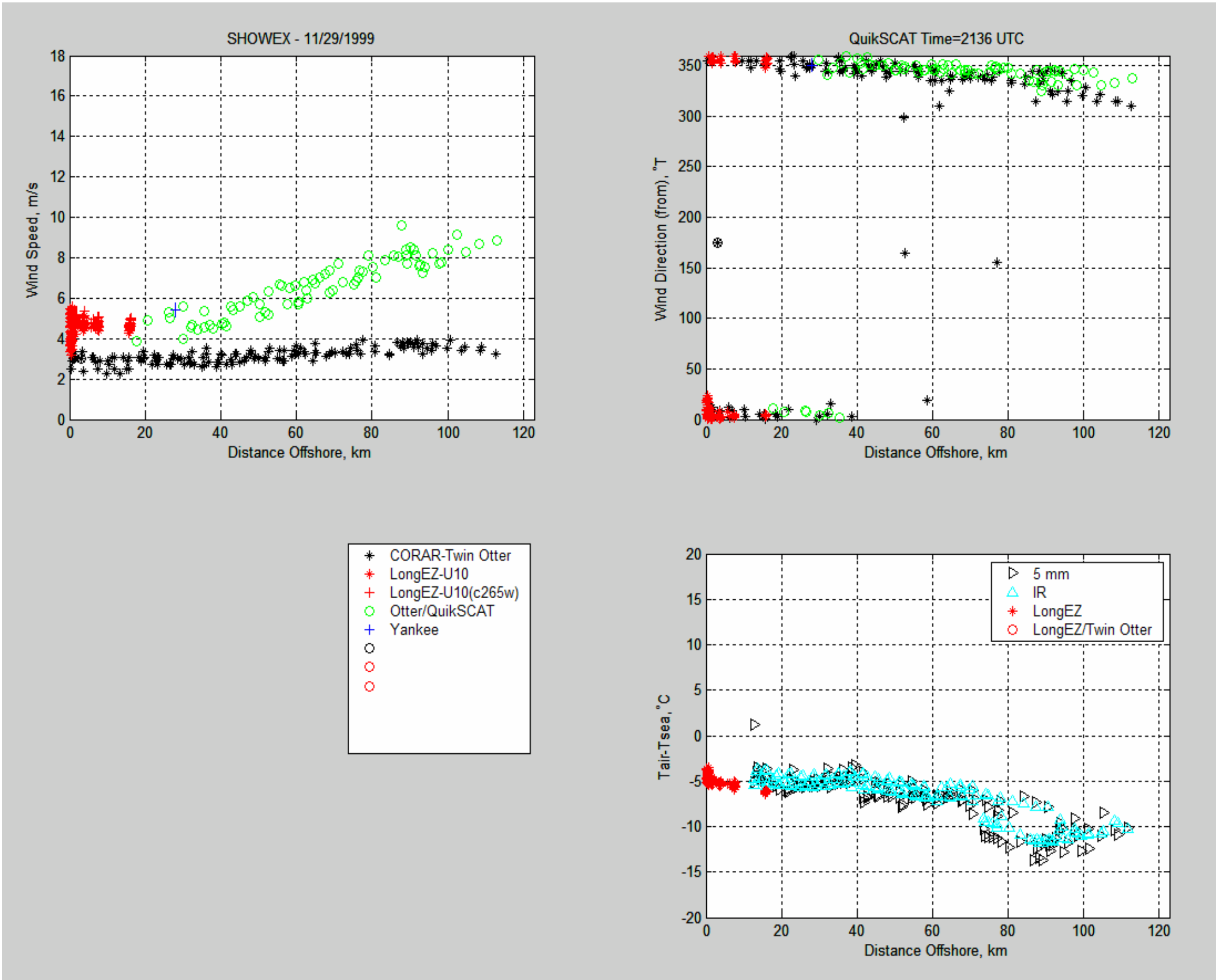

Figure 3. Comparison of CORAR winds with high-resolution QuikSCAT winds on a day when the atmosphere was unstable.

Wind directions from the two scatterometers agreed very well, both when the air temperature is lower (unstable) and higher (stable) than the water temperature. Under stable conditions (Figure 2), the wind speeds also agreed well but under unstable conditions (Figure 3), they diverged, and diverged more as conditions became more unstable.

Since the incidence angles of the two scatterometers are nearly the same (45^o to 55^o) and the wind speeds are low, their backscatter is due to two Bragg waves that are only slightly different, about 2 cm at X-band and 1.4 cm at Ku-band, and it seems strange that their behavior would depend so differently on atmospheric conditions. A possible explanation for this discrepancy is that the wind speed is near threshold for these wavelengths (Donelan and Pierson, 1987). The high resolution technique applied to QuikSCAT data begins with the full scatterometer resolution cell of 6 by 25 km. If the wind speed exceeds threshold more often within this large cell than it does within the smaller cell that determines the final resolution, the technique may yield a result that is biased high. We are continuing to investigate this possibility.

IMPACT/APPLICATION

This project will shed new light on the interactions among wind, waves, and bottom that occur when long ocean waves propagate onto continental shelves. In addition to this scientifically interesting impact, the results will also allow an assessment of the feasibility of determining ocean conditions near denied coastlines by means of coherent radars mounted on remotely piloted vehicles.

TRANSITIONS

CORAR has not yet been transitioned.

RELATED PROJECTS

Closely related projects are the other ONR projects dealing with SHOWEX data, an NSF funded project to obtain high-resolution winds near shorelines from the RADARSAT SAR, and a NASA project attempting to extract high-resolution wind fields from QuikSCAT data.

REFERENCES

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